CHARACTERIZATION OF CAPILLARY DISCHARGE WATER-WINDOW RADIATION SOURCE

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Introduction

Intense XUV radiation in "**water-window**" region was generated by spectral line emission of **Nitrogen** or **Argon** ions in Z-pinching capillary plasma.

Following measurements were carried out:

- Capillary **current** and XUV radiation **power**.
- Radiation **energy** per pulse.
- Beam **profile**.
- Beam **divergence**.
- Source **size**.`
- Time-integrated **spectra** (see Poster **S23**).

Capillary plasma driver

- **21 nF** capacitor bank
- **70 kV** capacitor charging voltage
  110 kV theoretical maximum *)
- Al_2O_3 capillary **10 cm** long **3.2 mm** inner dia.
- Maximum current **23 kA**
  33 kA theoretical maximum*)
- Capillary current rise-time **60 ns**, T/2 = **150 ns**

*) PSPICE estimation

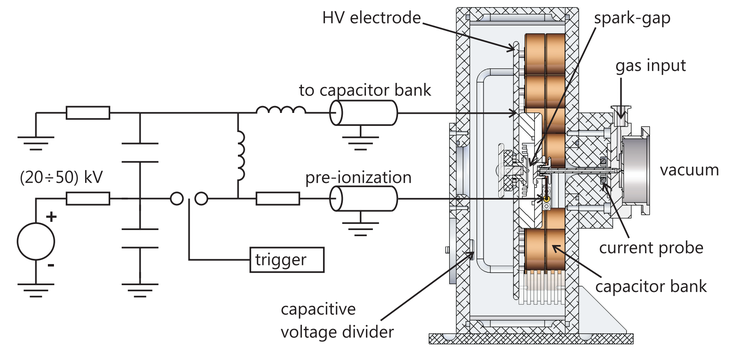

FIG. 1 Capillary plasma driver and charging circuit

Results

Nitrogen

Beam profile, beam divergence and source size

- profile measured by **BI-CCD** - measurement setup on Fig. 2 top,
- source size measured by **30 µm pinhole** image, also using **BI-CCD** camera - measurement setup on Fig. 2 bottom,
- **500 nm** thick **Titanium filter** used as water-window band-pass

Results:

Beam divergence..... $\theta_{FWHM} \approx 30$ **mrad** ($\Omega_{FWHM} \approx 7e\text{-}4$ **sr**)
Source size..... $D_{FWHM} \approx 360$ **µm**

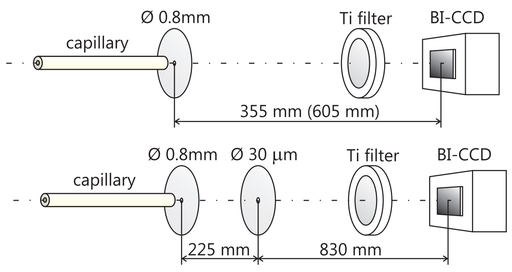

FIG. 2 Beam profile (top) and source size (bottom) measurement layout

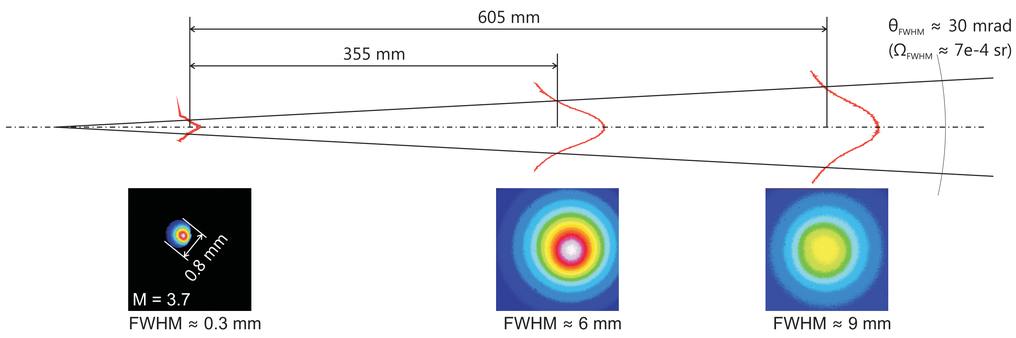

FIG. 3 **Beam profile**, **divergence** and **source size** measurement results. Pictures from left: source pinhole image recorded with magnification M=3.7, beam profile 355 mm from capillary exit, beam profile 605 mm from capillary exit. Corresponding line profiles are plotted above pictures.

Capillary current, XUV power, and XUV energy/pulse

- capillary **current** measured by **Rogowski coil**
- XUV **power** measured by **AXUV PIN diode** – measurement setup on FIG. 4,
- XUV **energy** determined by **numerical integration**,
- **500 nm** thick **Titanium filter** used as water-window band-pass

2 changeable initial condition:

1) Capillary **current amplitude**
2) Initial capillary filling **gas pressure**

Results:

Maximum **XUV energy** (@ 60 Pa, 22.3 kA)..... **2.3 mJ/sr**
Maximum **XUV peak power** (@ 140 Pa, 22.4 kA)..... **106 kW/sr**

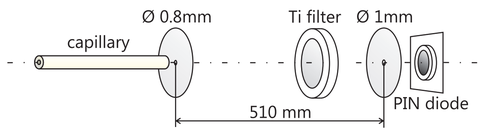

FIG. 4 XUV radiation power measurement setup (Nitrogen)

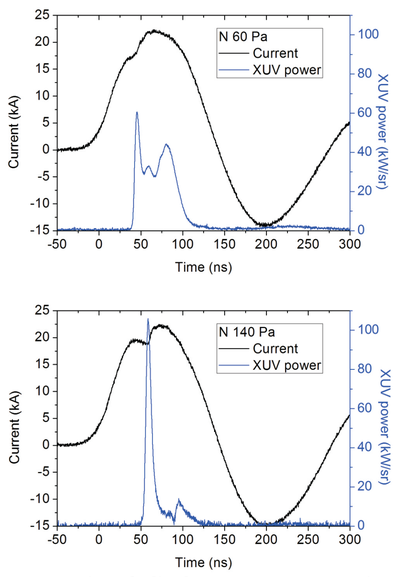

FIG. 5 Sample of **discharge current** and **XUV radiation power** measurement for **60 Pa** – top, and **140 Pa** – bottom. At 60 Pa, the **maximum energy/pulse** was achieved. At 160 Pa, the **maximum peak power** was achieved – see FIG. 7.

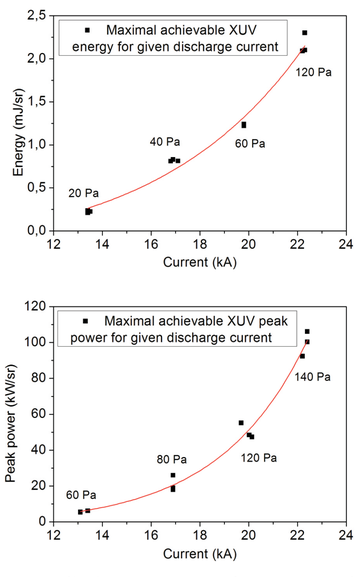

FIG. 6 XUV radiation **energy**/pulse – top, and XUV peak **power** – bottom, **with respect to** discharge **current amplitude**. For every current, the **optimum gas pressure** was set – values in the graph.

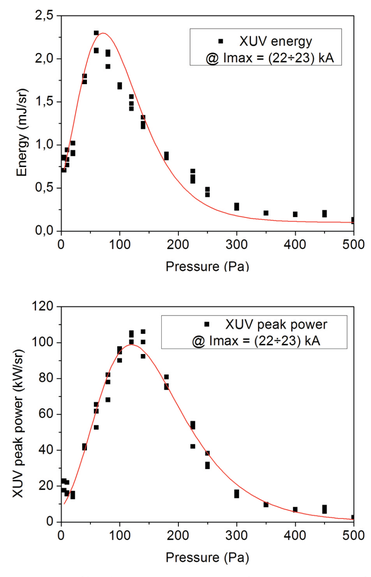

FIG. 7 XUV radiation **energy**/pulse – top, and XUV peak **power** – bottom, **with respect to** capillary **gas** filling **pressure** at fixed discharge current **22÷23 kA**.

Argon

Capillary current, XUV power, and XUV energy/pulse

Results:

Maximum **XUV energy** (@ 15 Pa, 20.8 kA):
9.5 mJ/sr

Maximum **XUV peak power** (@ 60 Pa, 20.2 kA)
250 kW/sr

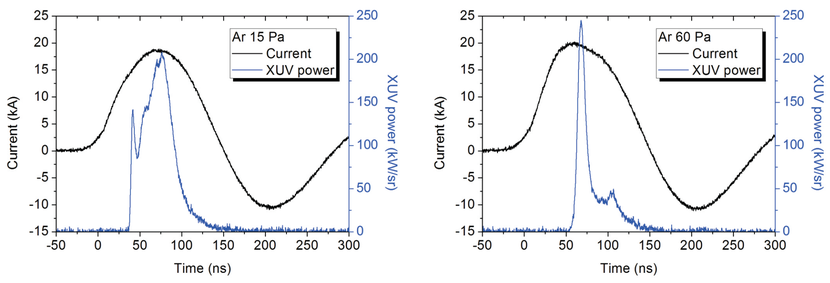

FIG. 8 Sample of **discharge current** and **XUV radiation power** measurement for **15 Pa** – left, and **60 Pa** – right. At 15 Pa, the **maximum energy/pulse** was achieved. At 60 Pa, the **maximum peak power** was achieved – see FIG.9.

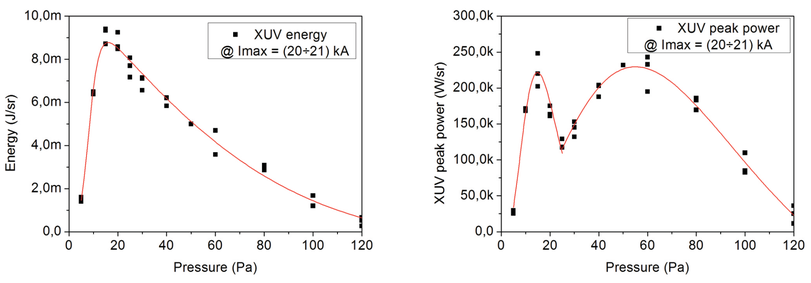

FIG. 9 XUV radiation **energy**/pulse – left, and XUV peak **power** – right, with respect to capillary **gas** filling **pressure** at fixed discharge current **20÷21 kA**.

Conclusion

Summary of achieved radiation quantities is listed below. These values were obtained by discharges with current amplitudes $I_{max} \approx 22.5$ **kA in nitrogen** and $I_{max} \approx 20.5$ **kA in Argon** and with fixed discharge energy $E_{CAP} = 82$ **J**. Another increase in radiation power and energy with respect to increasing discharge current is expected – see FIG. 6.

NITROGEN		ARGON	
Energy/pulse per sr:	E_Ω = 2.3 mJ/sr	Energy/pulse per sr:	E_Ω = 9.5 mJ/sr
Energy/pulse in 1σ of the beam:	$E_{1\sigma}$ = 70 nJ	Energy/pulse in 1σ of the beam:	$E_{1\sigma}$ = 300 nJ
Source Efficiency *):	8.5e-10	Source Efficiency *):	3.7e-9
Peak power per sr:	P_Ω = 106 kW/sr	Peak power per sr:	P_Ω = 250 kW/sr
Peak power in 1σ of the beam:	$P_{1\sigma}$ = 3.4 W	Peak power in 1σ of the beam:	$P_{1\sigma}$ = 7.9 W
Peak brightness:	L = 1.5 W/mrad²/mm²	Peak brightness:	L = 3.5 W/mrad²/mm²

*) radiation $E_{1\sigma}$ / capacitor stored energy

Acknowledgements

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References

For spectral characteristics see poster no. S23: NOVAK J - Measurement of Spectra in Water-window Wavelength Region